Naval Surface Warfare Center
Carderock Division
West Bethesda, MD 20817-5700

NSWCCD-CISD–2007/004 August 2007

Ship Systems Intregration & Design Department

Technical Report

Development of a High-Capacity, High-Speed Sealift Hullform

By

John Fishback

Alexander Kan May

Unrestricted Distribution

NSWCCD-CISD–2007/004

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
10-August-2007

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*
21-May-2007 – 10-Aug-2007

4. TITLE AND SUBTITLE
Development of a High-Capacity, High-Speed Sealift Hullform

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
John Fishback and Alexander May

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)
Naval Surface Warfare Center
Carderock Division
9500 Macarthur Boulevard
West Bethesda, MD 20817-5700

8. PERFORMING ORGANIZATION REPORT NUMBER
NSWCCD-CISD-2007/004

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
875 North Randolph Street
Arlington, VA 22203-1995

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Unrestricted Distribution

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Sealift vessels are responsible for transporting the bulk of military equipment and vehicles overseas. The aim of this research is to develop a hull capable of reaching an austere destination at high speed while maintaining the high capacity of a sealift ship. A hull form with short longitudinal effective length will generate a high Froude number, of approximately 0.7, at the desired cruise velocity. Theoretically, the wake and frictional resistances will be reduced as a result. To achieve the large displacement of a useful sealift vessel, the hull of the ship will sweep out and back from the centerline of the ship so as to maintain the short longitudinal effective length while maintaining an efficient bow form. Additionally, this design must be capable of landing at an austere port. The austere port is a hypothetical landing site of limited accommodations; superimposing limits on the length, beam, and draft of the vessels landing within it. This research seeks to develop a virtual hull with the eventual goal of model testing. The virtual model will be put through hydrodynamic testing as appropriate for a conceptual ship design at the Naval Surface Warfare Center, Carderock Division (NSWCCD).

15. SUBJECT TERMS
Hull design, sealift, high-speed vessel, high Froude number

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	None	18	Colen Kennell
					19b. TELEPHONE NUMBER *(include area code)* 301-227-5468

Abstract

Sealift vessels are responsible for transporting the bulk of military equipment and vehicles overseas. The aim of this research is to develop a hull capable of reaching an austere destination at high speed while maintaining the high capacity of a sealift ship. A hull form with short longitudinal effective length will generate a high Froude number, of approximately 0.7, at the desired cruise velocity. Theoretically, the wake and frictional resistances will be reduced as a result. To achieve the large displacement of a useful sealift vessel, the hull of the ship will sweep out and back from the centerline of the ship so as to maintain the short longitudinal effective length while maintaining an efficient bow form. Additionally, this design must be capable of landing at an austere port. The austere port is a hypothetical landing site of limited accommodations; superimposing limits on the length, beam, and draft of the vessels landing within it. This research seeks to develop a virtual hull with the eventual goal of model testing. The virtual model will be put through hydrodynamic testing as appropriate for a conceptual ship design at the Naval Surface Warfare Center, Carderock Division (NSWCCD).

Acknowledgments

This report is the culmination of work conducted by students hired under the National Research Enterprise Intern Program sponsored by the Office of Naval Research. This program provides an opportunity for students to participate in research at a Department of Navy laboratory for 10 weeks during the summer. The goals of the program are to encourage participating students to pursue science and engineering careers, to further education via mentoring by laboratory personnel and their participation in research, and to make them aware of Navy research and technology efforts, which can lead to future employment.

At the Naval Surface Warfare Center Carderock Division, the single largest employer of summer interns is the Center for Innovation in Ship Design (CISD), which is part of the Ship Systems Integration and Design Department. The intern program is just one way in which CISD fulfils its role of conducting student outreach and developing ship designers.

The student team consisted of:

John Fishback — University of Rochester

Alexander Kan May — Carnegie Mellon

The team would like to acknowledge their mentors:

- Mr. Gabor Karafiath,
- Dr. Dane Hendrix, and
- Dr. Francis Noblesse.

The team would also like to recognize their fellow student researchers:

- Dennis So Ting Fong, and
- Trevor Blanarik.

Table of Contents

Table of Figures

Introduction

The report summarizes the design work undertaken to develop a TwinTail (TT) hull series. There were three primary goals for this hull design. The hull must be capable of:

1. transporting the required cargo,
2. traveling at high velocity across various sea states, and
3. landing at an austere port.

The lead researcher decided that the sealift vessel should have a displacement of at least 20,000 long tons (44,800,000 pounds). The hull form was also to be designed to travel at a cruise speed of 45 knots. Furthermore, the austere port limits the dimensions of the ship to be of length less than 650 ft (ideally 500 ft), beam less than 120 ft (ideally 100 ft), and a draft of less than 25 ft (ideally 15 ft).

The three primary goals significantly influenced the hullform design and the final design represented a compromise between them. The high velocity coupled with the high capacity of the ship was possible to achieve by designing the hull to operate at supercritical Froude numbers (greater than 0.7) thereby lowering the overall resistance.

Early Work and Proposed Solutions

The Rhinoceros 3.0 NURBS modeling program (“Rhino”) was used to generate surfaces to simulate the hull of the proposed ship. A destroyer hull, Model 4787 of Series 64, had already been modeled and was used as the basis for the experimental hull. The destroyer hull was proven to be fast and it was assumed that its profile would be a logical starting point for designing a similarly fast ship by changing aspects of the hull (e.g., beam).

Early designs resembled trimarans with a single deck, partially below the water surface to increase displacement. After further discussion, the student researchers understood that the design would have to be a more streamlined, single hull of a more unique configuration. Figure 1 illustrates an early design concept.

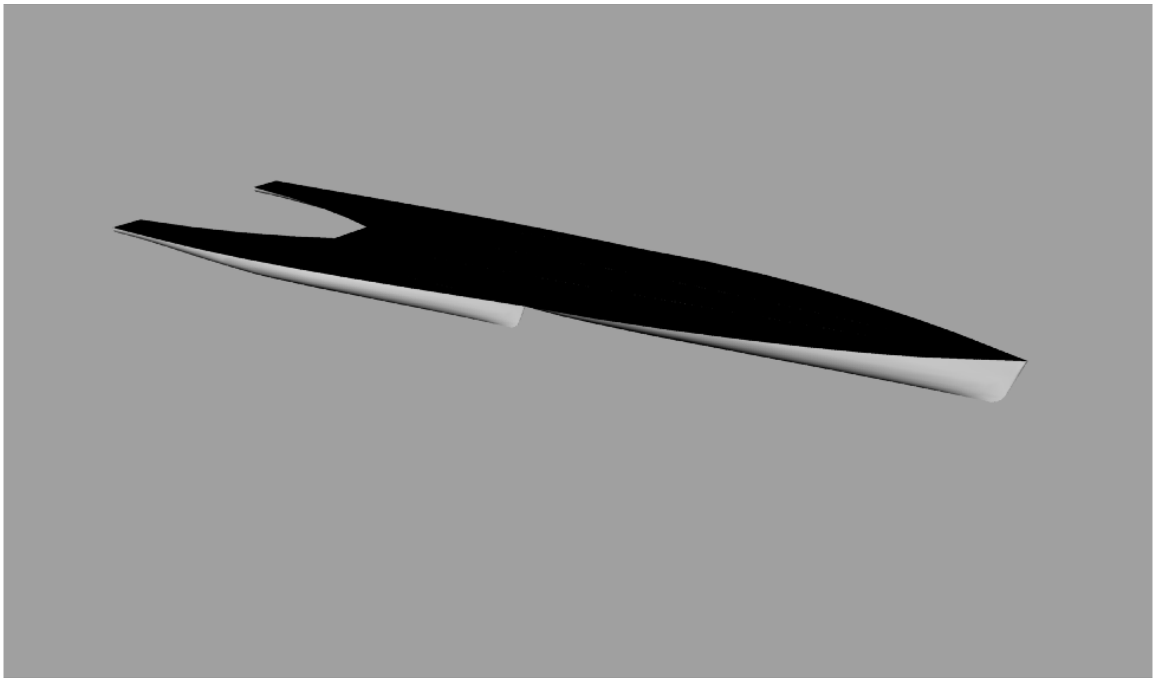


Figure 1: An early design concept, having three hulls and a deck section designed to be partially submerged to increase buoyancy

Attempts have been made in the past to achieve supercritical Froude numbers to reduce overall resistance. The "Sea Slice" vessel (Figure 2) rides on four streamlined submerged hulls connected to the dry deck. In contrast, the TwinTail project focused on designing a monohull vessel capable of high speed and greater capacity with the ability to dock at austere ports.

Figure 2: "Sea Slice" – An implementation of supercritical Froude number in hull design

(Image courtesy of http://commons.wikimedia.org/wiki/Image:Sea_Slice_returnes_to_homeport.jpg)

The proposed method of accomplishing supercritical Froude numbers in the monohull was to design it to have a short effective hull length. The effective hull length is the length of the ship parallel to the centerline, which is used to calculate the Froude number. Usually, the effective hull length is similar to that taken from along the centerline. It is possible that this may not be the case, but for experimental purposes, the effective length will be assumed to be along the centerline. In order to have the capacity required of a sealift ship, this vessel will have its profile stretched aft and out from the short centerline, as preliminarily exhibited in Figure 1. In order for this effective hull length to be valid, the researchers felt it important to have the majority of the flow pass under the hull as opposed to around it. Thus, the fluid surrounding the vessel traverses a much shorter distance in contact with the hull.

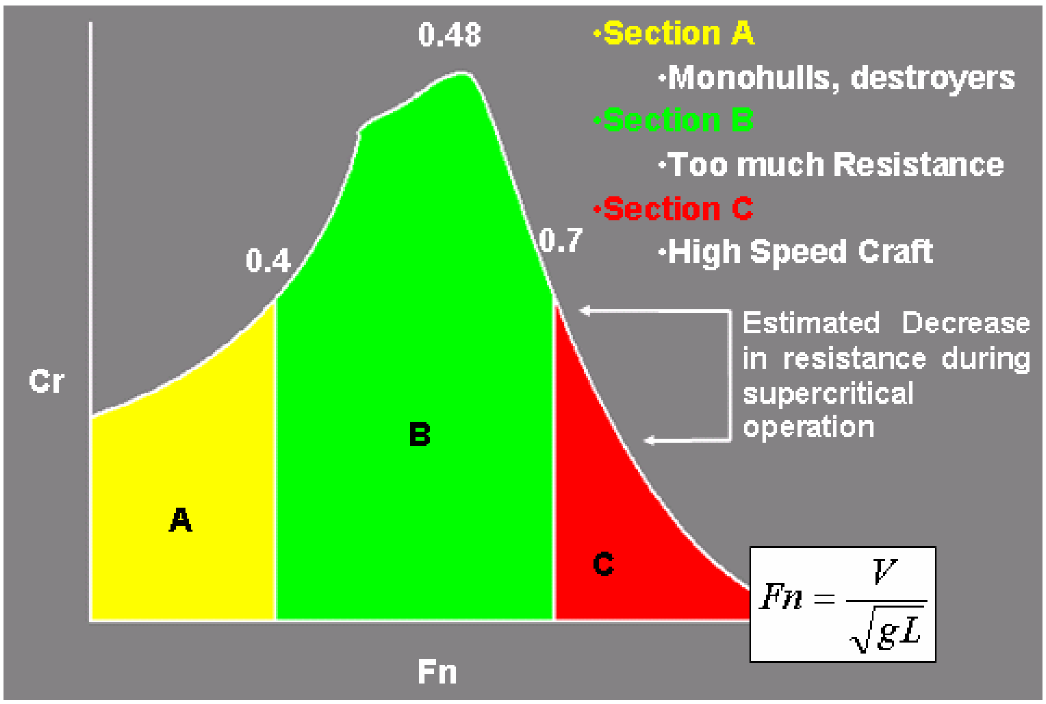


Figure 3: Illustrative Graph of Resistance Vs. Froude Number with Target Values

Rhinoceros Surface Modeling

The task of adequately defining the required volume was one of the most difficult. To create a smooth hull, the basic destroyer hull was discarded. Figures 4 and 5 illustrate the namesake “twin tails” that are the result of sweeping a hull profile out and back from the centerline of the vessel. The mentors for this project supervised the many iterations of this design and offered several explanations concerning the vessel’s hydrodynamics.

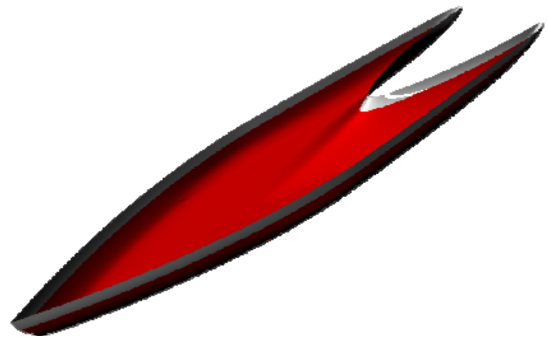


Figure 4: Isometric Underside Views of a Preliminary Hull Form

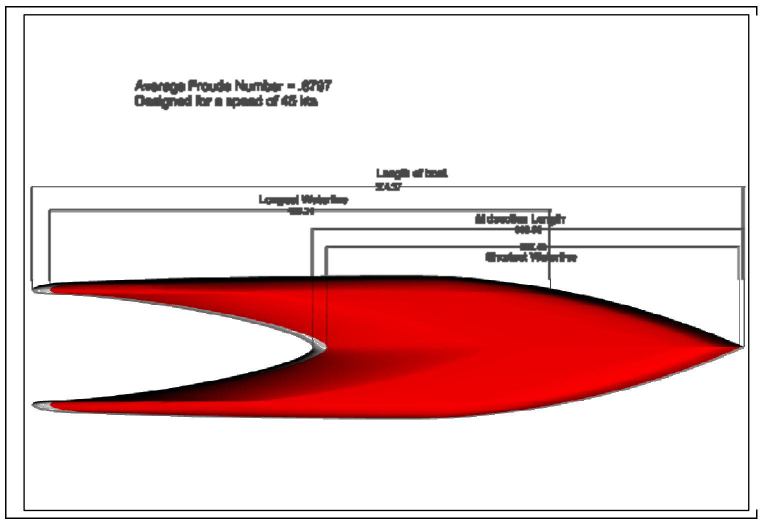


Figure 5: Dimensioned Underside Views of a Preliminary Hull Form

It should be noted that, even in the current models, the longest longitudinal wetted hull section is over 400 ft. However, the centerline wetted hull is relatively short, only about 330 ft. This centerline length is the basis for the Froude number calculation and is theoretically much more significant than the trailing tails, where the hull section is longer. It was also decided that this hull model would be fitted with transoms at the ends of the tails to allow for 15 ft diameter waterjets. Realistic dimensions very close to the constraints of the austere port were chosen and cruise velocity is expected to be between 35 knots and 45 knots. Present power systems indicate that 45 knots is a fairly unrealistic target speed for this size ship.

The models shown in the figures below do not have transoms modeled, but they would have if they were to be produced either in model or full scale. These models are also colored for the reader's reference, separate colors being used to differentiate between the portions above and below the waterline.

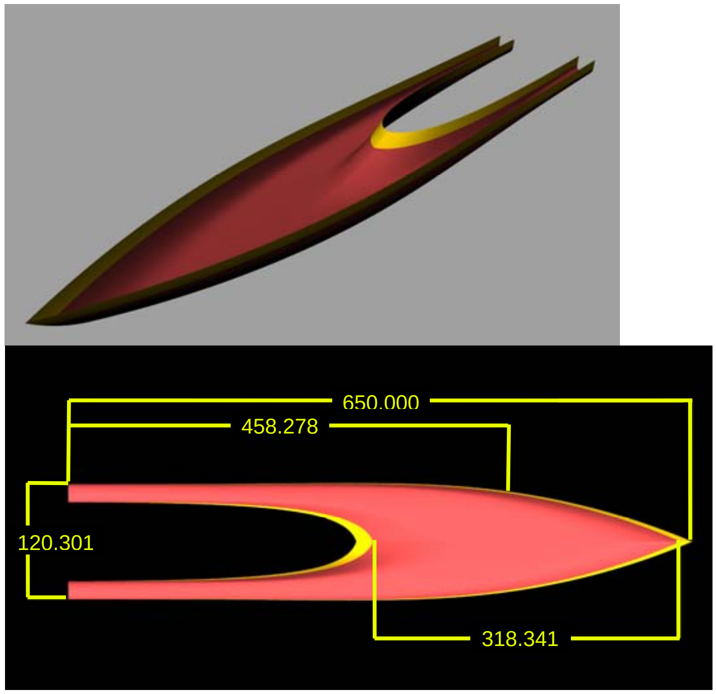


Figure 6: Isometric and Dimensioned Underside Views of TT001

The TwinTail hull design designated as TT001 was evaluated using Hydrostatics and Flow Code programs. The applied revisions included adding a transom to the area between the tails, widening the tails, and further reducing the angle of the bow. This set of revisions is referred to as design iteration TT002.

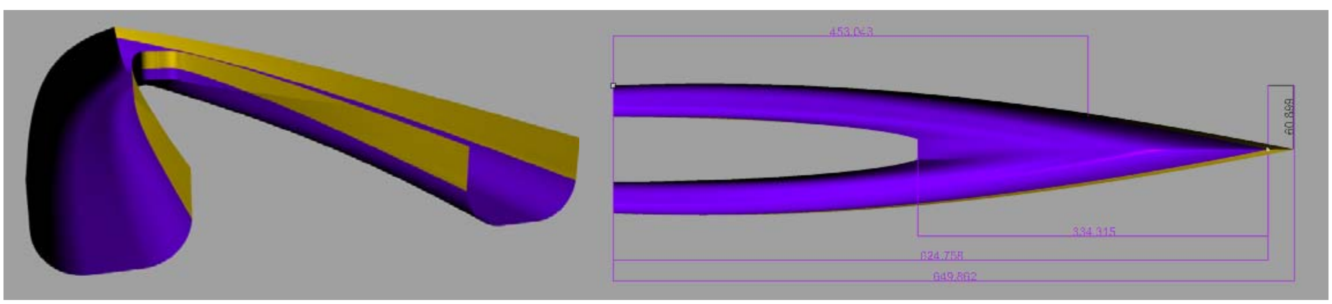


Figure 7: Isometric and Dimensioned Underside Views of TT002

Hydrostatics Analysis

The results of the Hydrostatics program are coefficients associated with the dimensions of the ship. One of the most useful results is a graph of the cross-sectional area against section number. The topmost plot of Figure 8 gives the reader an idea of the distribution of cross-sectional area on TT001. After seeing these Hydrostatics results, the mentors suggested that the vessel would have better performance if the largest cross-sectional area occurred closer to station 10 rather than station 8.

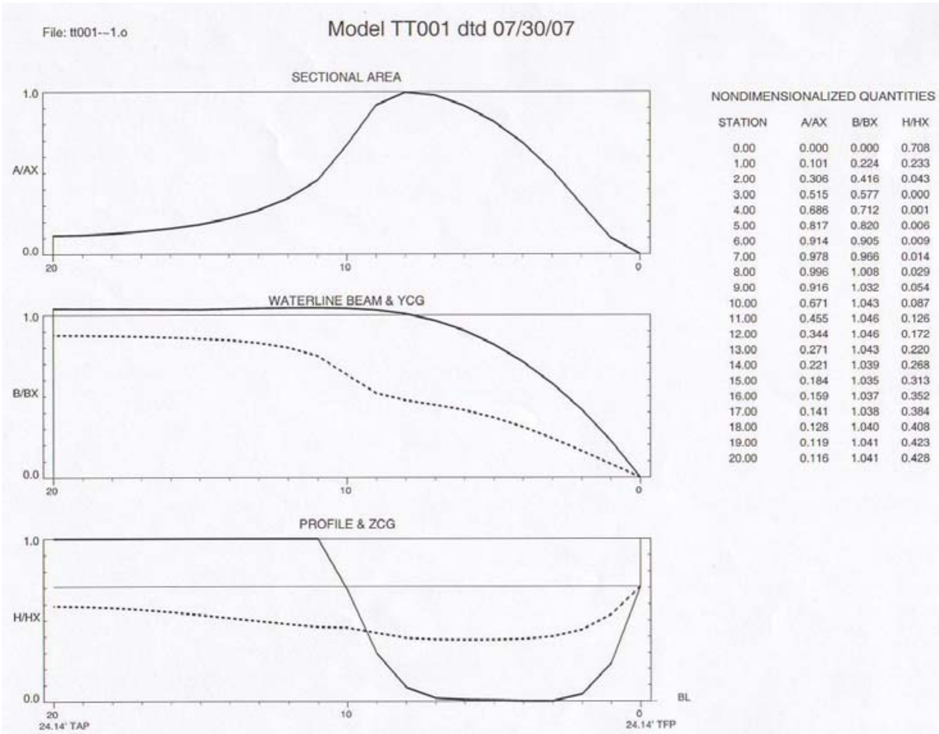


Figure 8: Distribution of Sectional Area, Waterline Beam, and Profile versus Station as Depicted by Hydrostatics (TT001)

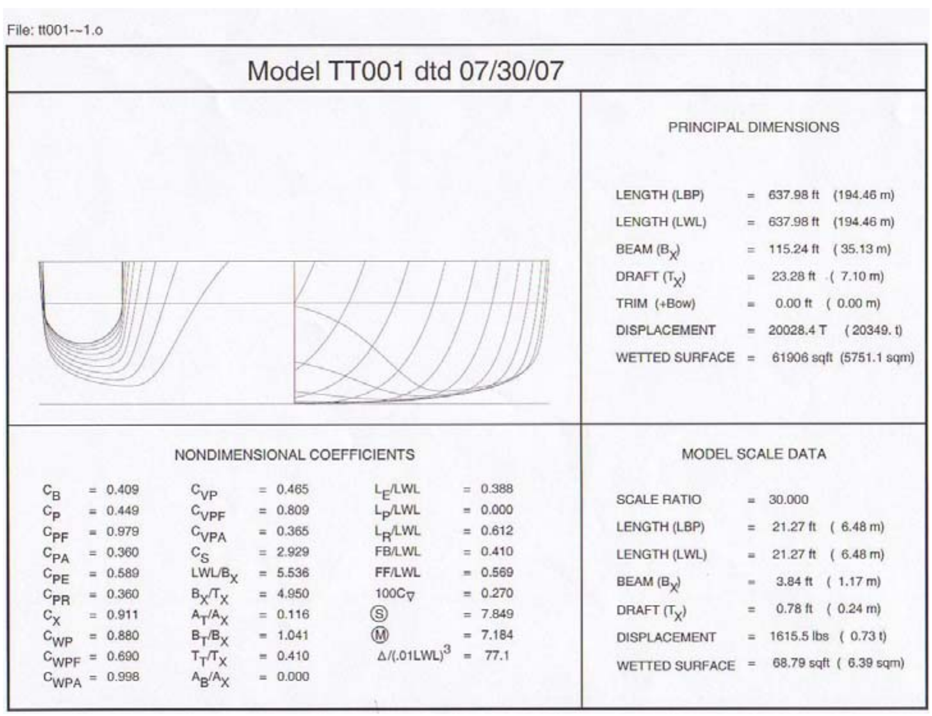
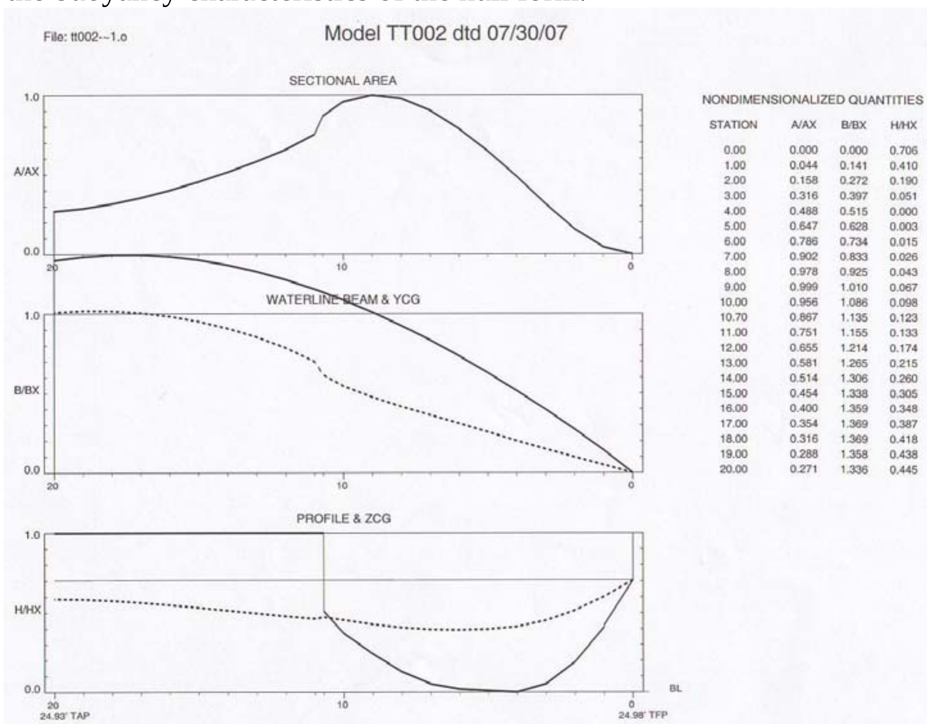


Figure 9: Ship Contours and Coefficients as Depicted by Hydrostatics (TT001)

After the revisions discussed in the Rhinoceros Surface Modeling section were made, the result was called TT002. It has an interior transom, wider tails, and a more shallow entrance angle. The improvements may be partially viewed through a comparison of the distribution of sectional area between Figure 8 and Figure 10. Not only has the maximum sectional area shifted aft, but the overall distribution is far more even. This should further improve the buoyancy characteristics of the hull form.



STATION	A/AX	B/BX	H/HX
0.00	0.000	0.000	0.706
1.00	0.044	0.141	0.410
2.00	0.158	0.272	0.190
3.00	0.316	0.397	0.051
4.00	0.488	0.515	0.000
5.00	0.647	0.628	0.003
6.00	0.786	0.734	0.015
7.00	0.902	0.833	0.026
8.00	0.978	0.925	0.043
9.00	0.999	1.010	0.067
10.00	0.956	1.086	0.098
10.70	0.867	1.135	0.123
11.00	0.751	1.155	0.133
12.00	0.655	1.214	0.174
13.00	0.581	1.265	0.215
14.00	0.514	1.306	0.260
15.00	0.454	1.338	0.305
16.00	0.400	1.359	0.348
17.00	0.354	1.369	0.387
18.00	0.316	1.369	0.418
19.00	0.288	1.358	0.438
20.00	0.271	1.336	0.445

Figure 10: Distribution of Sectional Area, Waterline Beam, and Profile versus Station as Depicted by Hydrostatics (TT002)

Flow Code Analysis

The results of the Flow Code program include a diagram of the hull, colored according to a gradient of low-to-high resistances (and accordingly, pressures). Using the diagram from TT001, the student researchers were able to implement mentor-suggested modifications. Primarily, the areas of concern on TT001 were the area between the tails at the end of the centerline, and at the middle portions of the tails. At the lower Froude number of 0.45, these areas had high and low resistances (respectively). To remedy these stress concentrations, a transom was created between the tails to allow flow separation and the tails were widened. To further encourage fluid to flow beneath the hull, the angles of the leading portions of the ship were further reduced.
The Flow Code Analysis of TT002 and subsequent models will help determine whether modifying the hull form has made a positive influence.

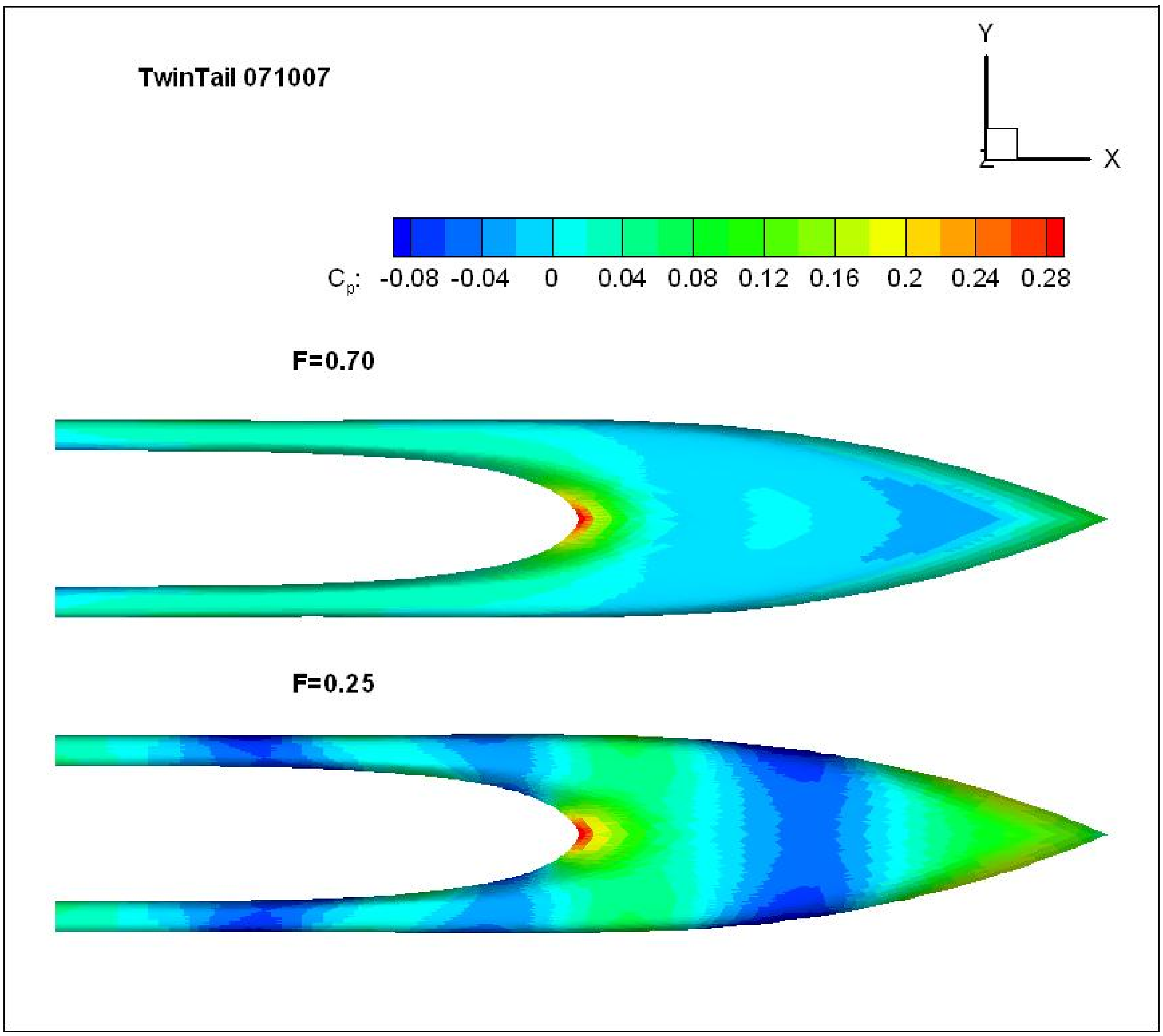


Figure 11: ***Flow Code Analysis of TT001***

Hydrodynamically-Similar Hull Form

Dr. Noblesse recommended that a hydrodynamically similar hull be modeled. This meant preserving as much as possible the buttocks profile and the basic features of displacement and length. It was also deemed important to make the hulls have similar stability characteristics. This was achieved by determining the transverse metacenter and transverse metacentric height. The transverse metacenter helps give an idea as to the rolling or heeling characteristics of the vessel. This hull will be used to compare the TT series to more conventional monohulls.

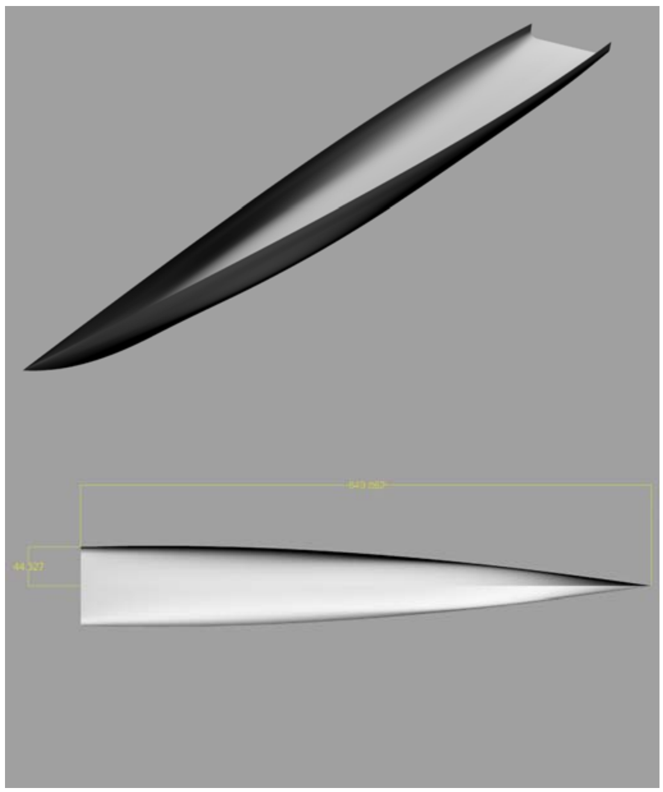
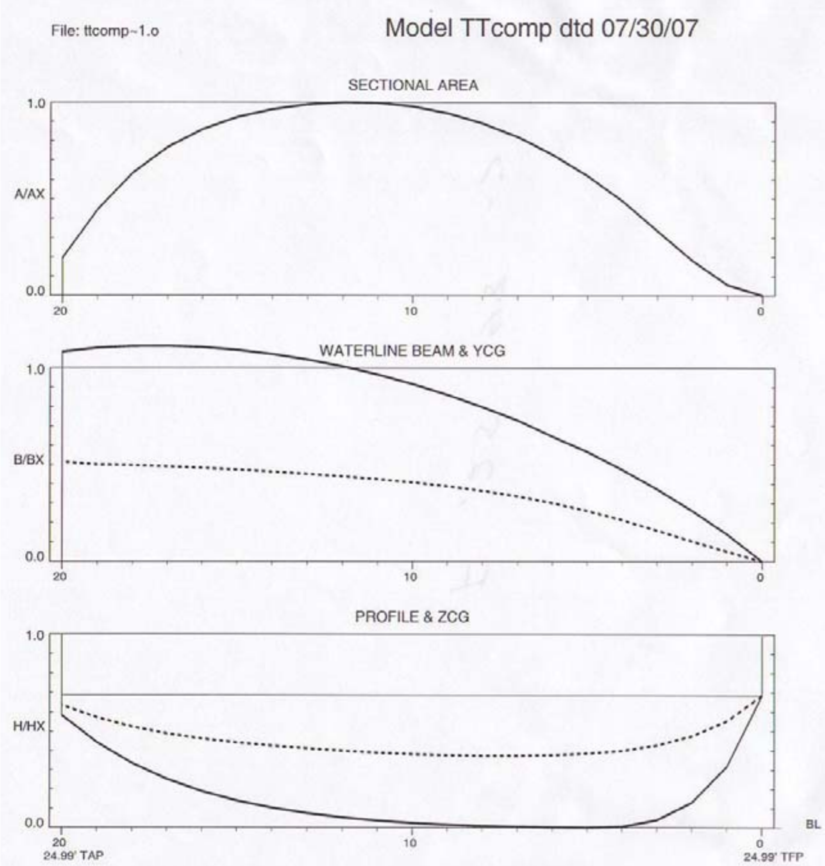


Figure 12: Isometric and Dimensioned Underside Views of a Comparison Hull Form



NONDIMENSIONALIZED QUANTITIES

STATION	A/AX	B/BX	H/HX
0.00	0.000	0.000	0.686
1.00	0.057	0.141	0.317
2.00	0.181	0.262	0.131
3.00	0.334	0.372	0.039
4.00	0.488	0.474	0.004
5.00	0.619	0.567	0.000
6.00	0.728	0.645	0.001
7.00	0.820	0.729	0.004
8.00	0.890	0.798	0.008
9.00	0.943	0.861	0.013
10.00	0.978	0.917	0.022
11.00	0.997	0.966	0.034
12.00	1.000	1.008	0.052
13.00	0.988	1.044	0.074
14.00	0.963	1.072	0.103
15.00	0.922	1.093	0.140
16.00	0.860	1.108	0.188
17.00	0.767	1.114	0.251
18.00	0.635	1.113	0.333
19.00	0.445	1.105	0.442
20.00	0.196	1.084	0.583

Figure 13: Distribution of Sectional Area, Waterline Beam, and Profile versus Station as Depicted by Hydrostatics (TTcomp)

Future Work

The design developed requires further iterations to produce a fully satisfactory hull form satisfying the design requirements. When the hull form has been adequately modified, a model may be made to measure resistance and determine the powering requirements of the vessel.

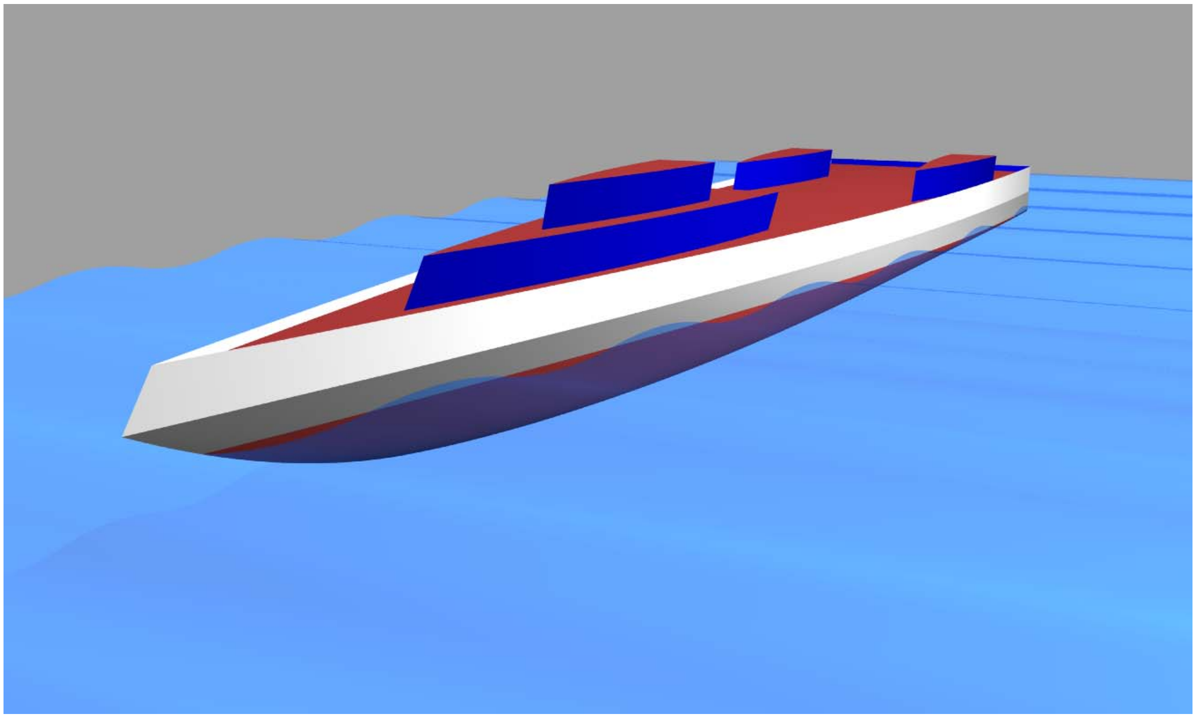


Figure 14: John Fishback's Artistic Interpretation of the Completed TwinTail

Conclusions and Results

A concept hull form was developed from concept to testing phases. The design is undergoing further revisions by Mr. John Fishback during the remainder of his internship at NSWCCD. The students represent the educational results of this project. During the summer of 2007, the student interns learned about the engineering design processes, how to use Rhinoceros to model designs with surfaces, and some critical aspects of hull design. In addition, they became familiar with some evaluation software used by naval architects at the NSWCCD and how they pertain to ship design.

The results of the project include a series of virtual hull forms (created in Rhinoceros 3.0), Hydrostatics and Flow Code analyses, and a hydrodynamically-similar hull form for comparison purposes. Additionally, this report exists to provide some insight as to the work completed by Mr. John Fishback and Mr. Alexander Kan May as NREIP interns between May and August of 2007; under the mentorship of Mr. Gabor Karafiath, Dr. Francis Noblesse, and Dr. Dane Hendrix.

Appendix 1: Hydrostatics Results

FILE: tt001--~1.off

Model TT001 dtd 07/30/07

TANK_ID :
HULL_ID :
MOD_ID :
COND_ID :

PRINCIPAL DIMENSIONS

	SHIP	MODEL		SHIP	MODEL
LOA (ft) :	637.98	21.266	B MAX (ft) :	120.58	4.019
LBP (ft) :	637.98	21.266	BX (ft) :	115.24	3.841
LWL (ft) :	637.98	21.266	BM (ft) :	120.23	4.008
LKEEL (ft) :	0.00	0.000	TFP (ft) :	24.14	0.805
DEPTH (ft) :	34.09	1.136	TAP (ft) :	24.14	0.805
VOL (ft^3) :	700443.1	25.942	TRIM (ft) :	0.00	0.000
DISP (lt) :	20028.4	0.721	TX (ft) :	23.28	0.776
WS (ft^2) :	61906.8	68.785	TM (ft) :	21.18	0.706
VDES (knts):	0.0	0.000	TNAV (ft) :	24.14	0.805
SCALE RATIO:	30.0000		RHOM :		1.9367

COEFFICIENTS

D_L :	77.13	CPF :	0.979	LWL/BX :	5.536	ABT/AX :	0.000
CB :	0.409	CPA :	0.360	BX/TX :	4.950	ABL/ABT :	0.000
CP :	0.449	CPE :	0.589	LE/LWL :	0.388	AT/AX :	0.116
CX :	0.911	CPR :	0.360	LP/LWL :	0.000	TT/TX :	0.410
CWP :	0.880	CWPF:	0.690	LR/LWL :	0.612	BT/BX :	1.041
CVP :	0.465	CWPA:	0.998	LCB/LWL :	0.410	BTUPD/BX:	0.529
CS :	2.929	CVPF:	0.809	LCF/LWL :	0.569	CIRC_S :	7.849
100CV:	0.270	CVPA:	0.365	V/LWL^.5:	0.000	CIRC_M :	7.184

ANGLES

IE (deg):	22.07	IE_UPD (deg):	20.60	STA_FP (deg):	??????
IR (deg):	-0.10	FLARE (deg):	6.73	STA_AP (deg):	0.000
IB (deg):	0.00	ROF (deg):	-3.89	TAY_T :	0.000

ARRAYS

STATION	A/AX	B/BX	G/(BX+2TX)	YCG/BX	ZCG/TX
0.00	0.000	0.000	0.000	0.000	1.000
1.00	0.101	0.224	0.259	0.081	0.746
2.00	0.306	0.416	0.429	0.162	0.610
3.00	0.515	0.577	0.560	0.239	0.548
4.00	0.686	0.712	0.666	0.310	0.526
5.00	0.817	0.820	0.751	0.368	0.520
6.00	0.914	0.905	0.816	0.413	0.519
7.00	0.978	0.966	0.862	0.446	0.522
8.00	0.996	1.008	0.893	0.475	0.537
9.00	0.916	1.032	0.922	0.519	0.582
10.00	0.671	1.043	0.987	0.633	0.630
11.00	0.455	1.046	0.746	0.748	0.636
12.00	0.344	1.046	0.651	0.799	0.661
13.00	0.271	1.043	0.581	0.829	0.689
14.00	0.221	1.039	0.525	0.846	0.717
15.00	0.184	1.035	0.477	0.855	0.745
16.00	0.159	1.037	0.440	0.863	0.771
17.00	0.141	1.038	0.411	0.868	0.793
18.00	0.128	1.040	0.389	0.872	0.811
19.00	0.119	1.041	0.375	0.875	0.822
20.00	0.116	1.041	0.370	0.876	0.826

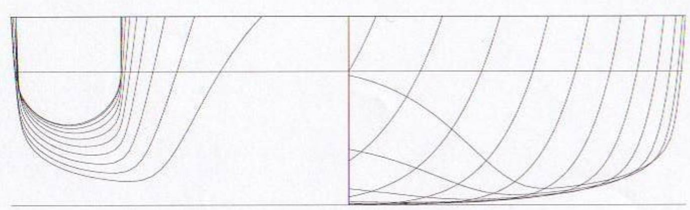
CHECKS

(LF+LA)/LWL	= 1.000000	CX/CM*(AM/AX)/(BM/BX)/(TM/TX)	= 1.000000
(LE+LP+LR)/LWL	= 1.000000	(CPF+CPA)/(2*CP)*AM/AX	= 1.000000
(VF+VA)/VOL	= 1.000000	(CPE*LE+CPR*LR+LP)/(LWL*CP)	= 0.998614
(VE+VP+VR)/VOL	= 0.998614	(CWPF+CWPA)/(2*CWP)*BM/BX	= 1.000000
(AWF+AWA)/AWT	= 1.000000	CB/CWP/CVP	= 1.000000
CP*CX/CB	= 1.000000		

((CVPA*AWA*TMA/TX)+(CVPF*AWF*TMF/TX))/(CVP*AWT) = 1.000000

File: tt001-~1.o

Model TT001 dtd 07/30/07



PRINCIPAL DIMENSIONS

LENGTH (LBP)	=	637.98 ft	(194.46 m)
LENGTH (LWL)	=	637.98 ft	(194.46 m)
BEAM (B_X)	=	115.24 ft	(35.13 m)
DRAFT (T_X)	=	23.28 ft	(7.10 m)
TRIM (+Bow)	=	0.00 ft	(0.00 m)
DISPLACEMENT	=	20028.4 T	(20349. t)
WETTED SURFACE	=	61906 sqft	(5751.1 sqm)

NONDIMENSIONAL COEFFICIENTS

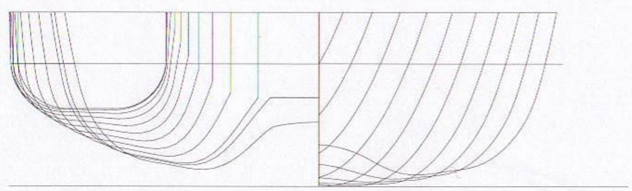
C_B	= 0.409	C_{VP}	= 0.465	L_E/LWL	= 0.388
C_P	= 0.449	C_{VPF}	= 0.809	L_P/LWL	= 0.000
C_{PF}	= 0.979	C_{VPA}	= 0.365	L_R/LWL	= 0.612
C_{PA}	= 0.360	C_S	= 2.929	FB/LWL	= 0.410
C_{PE}	= 0.589	LWL/B_X	= 5.536	FF/LWL	= 0.569
C_{PR}	= 0.360	B_X/T_X	= 4.950	$100C_\nabla$	= 0.270
C_X	= 0.911	A_T/A_X	= 0.116	S	= 7.849
C_{WP}	= 0.880	B_T/B_X	= 1.041	M	= 7.184
C_{WPF}	= 0.690	T_T/T_X	= 0.410	$\Delta/(.01LWL)^3$	= 77.1
C_{WPA}	= 0.998	A_B/A_X	= 0.000		

MODEL SCALE DATA

SCALE RATIO	=	30.000	
LENGTH (LBP)	=	21.27 ft	(6.48 m)
LENGTH (LWL)	=	21.27 ft	(6.48 m)
BEAM (B_X)	=	3.84 ft	(1.17 m)
DRAFT (T_X)	=	0.78 ft	(0.24 m)
DISPLACEMENT	=	1615.5 lbs	(0.73 t)
WETTED SURFACE	=	68.79 sqft	(6.39 sqm)

File: tt002--1.o

Model TT002 dtd 07/30/07



PRINCIPAL DIMENSIONS

LENGTH (LBP)	= 624.76 ft	(190.43 m)
LENGTH (LWL)	= 624.76 ft	(190.43 m)
BEAM (B_X)	= 91.14 ft	(27.78 m)
DRAFT (T_X)	= 22.68 ft	(6.91 m)
TRIM (+Bow)	= 0.05 ft	(0.02 m)
DISPLACEMENT	= 16339.9 T	(16601. t)
WETTED SURFACE	= 56908 sqft	(5286.8 sqm)

NONDIMENSIONAL COEFFICIENTS

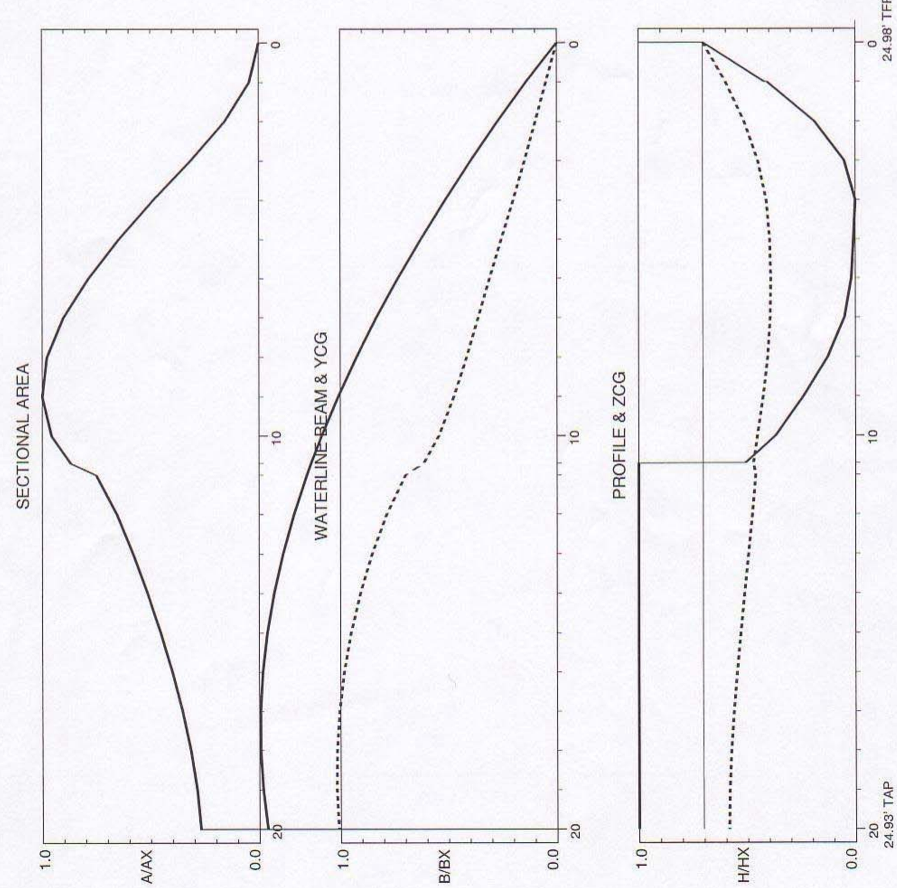
C_B	= 0.443	C_{VP}	= 0.467	L_E/LWL	= 0.444
C_P	= 0.537	C_{VPF}	= 0.725	L_P/LWL	= 0.000
C_{PF}	= 0.605	C_{VPA}	= 0.505	L_R/LWL	= 0.556
C_{PA}	= 0.518	C_S	= 3.012	FB/LWL	= 0.503
C_{PE}	= 0.528	LWL/B_X	= 6.855	FF/LWL	= 0.621
C_{PR}	= 0.544	B_X/T_X	= 4.019	$100C_\nabla$	= 0.234
C_X	= 0.824	A_T/A_X	= 0.271	Ⓢ	= 8.264
C_{WP}	= 0.947	B_T/B_X	= 1.336	Ⓜ	= 7.529
C_{WPF}	= 0.553	T_T/T_X	= 0.404	$\Delta/(.01LWL)^3$	= 67.0
C_{WPA}	= 1.192	A_B/A_X	= 0.000		

MODEL SCALE DATA

SCALE RATIO	= 30.000	
LENGTH (LBP)	= 20.83 ft	(6.35 m)
LENGTH (LWL)	= 20.83 ft	(6.35 m)
BEAM (B_X)	= 3.04 ft	(0.93 m)
DRAFT (T_X)	= 0.76 ft	(0.23 m)
DISPLACEMENT	= 1318.0 lbs	(0.60 t)
WETTED SURFACE	= 63.23 sqft	(5.87 sqm)

File: tt002~1.o

Model TT002 dtd 07/30/07



NONDIMENSIONALIZED QUANTITIES

STATION	A/AX	B/BX	H/HX
0.00	0.000	0.000	0.706
1.00	0.044	0.141	0.410
2.00	0.158	0.272	0.190
3.00	0.316	0.397	0.051
4.00	0.488	0.515	0.000
5.00	0.647	0.628	0.003
6.00	0.786	0.734	0.015
7.00	0.902	0.833	0.026
8.00	0.978	0.925	0.043
9.00	0.999	1.010	0.067
10.00	0.956	1.086	0.098
10.70	0.867	1.135	0.123
11.00	0.751	1.155	0.133
12.00	0.655	1.214	0.174
13.00	0.581	1.265	0.215
14.00	0.514	1.306	0.260
15.00	0.454	1.338	0.305
16.00	0.400	1.359	0.348
17.00	0.354	1.369	0.387
18.00	0.316	1.369	0.418
19.00	0.288	1.358	0.438
20.00	0.271	1.336	0.445

FILE: ttcomp~1.off

Model TTcomp dtd 07/30/07

TANK_ID :
HULL_ID :
MOD_ID :
COND_ID :

PRINCIPAL DIMENSIONS

	SHIP	MODEL		SHIP	MODEL
LOA (ft) :	633.26	21.109	B MAX (ft) :	88.52	2.951
LBP (ft) :	633.26	21.109	BX (ft) :	79.44	2.648
LWL (ft) :	633.26	21.109	BM (ft) :	72.87	2.429
LKEEL (ft) :	0.00	0.000	TFP (ft) :	24.99	0.833
DEPTH (ft) :	36.45	1.215	TAP (ft) :	24.99	0.833
VOL (ft^3) :	675418.2	25.015	TRIM (ft) :	0.00	0.000
DISP (lt) :	19312.8	0.695	TX (ft) :	23.24	0.775
WS (ft^2) :	54967.1	61.075	TM (ft) :	24.20	0.807
VDES (knts):	0.0	0.000	TNAV (ft) :	24.99	0.833
SCALE RATIO:	30.0000		RHOM :		1.9367

COEFFICIENTS

D_L :	76.05	CPF :	0.567	LWL/BX :	7.972	ABT/AX :	0.000
CB :	0.578	CPA :	0.835	BX/TX :	3.418	ABL/ABT :	0.000
CP :	0.686	CPE :	0.621	LE/LWL :	0.589	AT/AX :	0.196
CX :	0.842	CPR :	0.779	LP/LWL :	0.000	TT/TX :	0.161
CWP :	0.797	CWPF:	0.579	LR/LWL :	0.411	BT/BX :	1.084
CVP :	0.725	CWPA:	1.158	LCB/LWL :	0.561	BTUPD/BX:	0.574
CS :	2.658	CVPF:	0.817	LCF/LWL :	0.611	CIRC_S :	7.140
100CV:	0.266	CVPA:	0.757	V/LWL^.5:	0.000	CIRC_M :	7.218

ANGLES

IE (deg):	10.03	IE_UPD (deg):	7.85	STA_FP (deg):	??????
IR (deg):	0.08	FLARE (deg):	10.49	STA_AP (deg):	9.127
IB (deg):	6.88	ROF (deg):	2.48	TAY_T :	0.000

ARRAYS

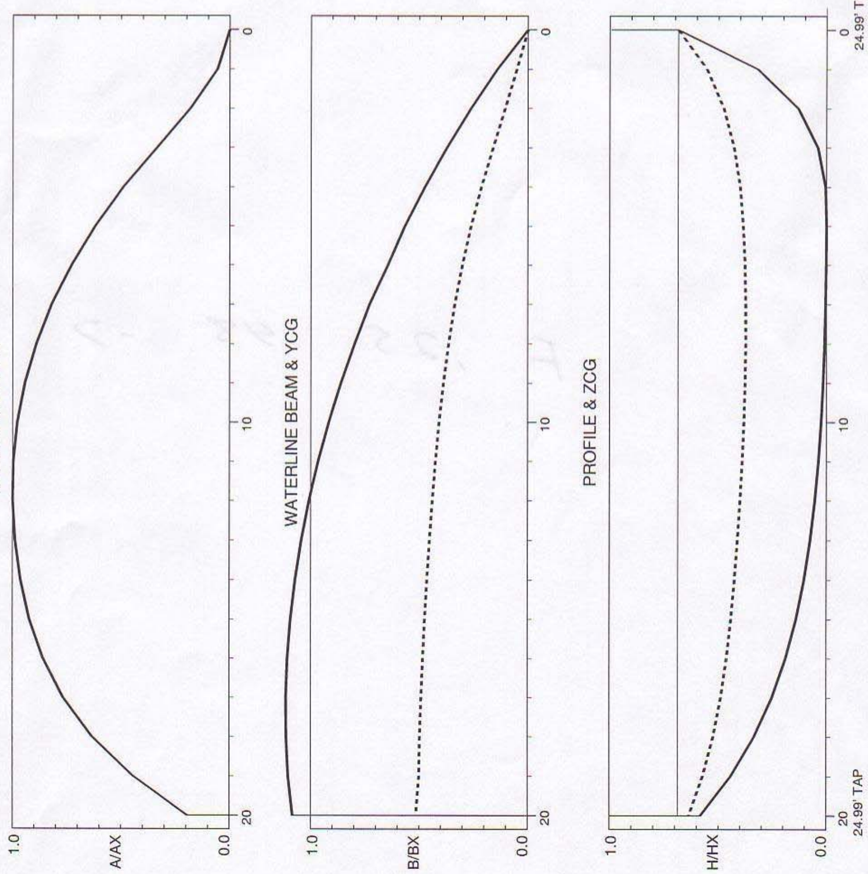
STATION	A/AX	B/BX	G/(BX+2TX)	YCG/BX	ZCG/TX
0.00	0.000	0.000	0.000	0.000	1.000
1.00	0.057	0.141	0.232	0.051	0.793
2.00	0.181	0.262	0.372	0.105	0.671
3.00	0.334	0.372	0.474	0.160	0.597
4.00	0.488	0.474	0.559	0.214	0.552
5.00	0.619	0.567	0.628	0.261	0.530
6.00	0.728	0.645	0.685	0.301	0.517
7.00	0.820	0.729	0.728	0.336	0.512
8.00	0.890	0.798	0.761	0.364	0.511
9.00	0.943	0.861	0.786	0.387	0.516
10.00	0.978	0.917	0.804	0.407	0.524
11.00	0.997	0.966	0.817	0.424	0.537
12.00	1.000	1.008	0.825	0.439	0.552
13.00	0.988	1.044	0.831	0.452	0.571
14.00	0.963	1.072	0.833	0.463	0.593
15.00	0.922	1.093	0.832	0.474	0.618
16.00	0.860	1.108	0.825	0.482	0.650
17.00	0.767	1.114	0.810	0.490	0.691
18.00	0.635	1.113	0.786	0.497	0.746
19.00	0.445	1.105	0.749	0.500	0.822
20.00	0.196	1.084	0.703	0.515	0.922

CHECKS

```
(LF+LA)/LWL     = 1.000000    CX/CM*(AM/AX)/(BM/BX)/(TM/TX) = 1.000000
(LE+LP+LR)/LWL = 1.000000    (CPF+CPA)/(2*CP)*AM/AX         = 0.999808
(VF+VA)/VOL     = 0.999808    (CPE*LE+CPR*LR+LP)/(LWL*CP)    = 0.999864
(VE+VP+VR)/VOL = 0.999864    (CWPF+CWPA)/(2*CWP)*BM/BX      = 0.999925
(AWF+AWA)/AWT   = 0.999925    CB/CWP/CVP                     = 1.000000
CP*CX/CB        = 1.000000
((CVPA*AWA*TMA/TX)+(CVPF*AWF*TMF/TX))/(CVP*AWT) = 0.999808
```

File: ttcomp~1.o

Model TTcomp dtd 07/30/07



NONDIMENSIONALIZED QUANTITIES

STATION	A/AX	B/BX	H/HX
0.00	0.000	0.000	0.686
1.00	0.057	0.141	0.317
2.00	0.181	0.262	0.131
3.00	0.334	0.372	0.039
4.00	0.488	0.474	0.004
5.00	0.619	0.567	0.000
6.00	0.728	0.645	0.001
7.00	0.820	0.729	0.004
8.00	0.890	0.798	0.008
9.00	0.943	0.861	0.013
10.00	0.978	0.917	0.022
11.00	0.997	0.966	0.034
12.00	1.000	1.008	0.052
13.00	0.988	1.044	0.074
14.00	0.963	1.072	0.103
15.00	0.922	1.093	0.140
16.00	0.860	1.108	0.188
17.00	0.767	1.114	0.251
18.00	0.635	1.113	0.333
19.00	0.445	1.105	0.442
20.00	0.196	1.084	0.583

IS

(193.02 m)
(193.02 m)
(24.21 m)
(7.08 m)
(0.00 m)
(19622. t)
t (5106.4 sqm)

(6.43 m)
(6.43 m)
(0.81 m)
(0.24 m)
(0.71 t)
t (5.67 sqm)